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ELECTROPHORETIC DISPLAY DEVICE

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Abstract: PURPOSE: To provide the electrophoretic display device capable of attaining a desired display-on-state or display-off-state by repeating a series of driving to discharge the charges accumulated in the electrophoretic display device or to neutralize the charges by reverse-polarity charges after first imparting the charges thereto, then to impart the charges of the same polarity as the polarity of the charges imparted to the device in the initial period and to discharge or neutralize these charges again.

CONSTITUTION: This electrophoretic display device makes desired display operation by sealing a dispersion 4 for electrophoretic display between a pair of substrates which are disposed to face each other and at least one of which are constituted of insulators 3 having no electrodes and impressing an electric field to this dispersion 4 via an electrostatic capacity of the substrates by the insulators 3 thereby changing the distribution state of electrophoresis particles 6, 7 in the dispersion 4. The above-mentioned electrophoretic display device is so constituted as to impress, plural times, the electric field for moving the electrophoresis particles 7 while changing the polarities of the electric field based on the operation of an ion gun 8.

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Specification

[Title of the Invention] ELECTROPHORESIS DISPLAY DEVICE

[Claims]

[Claim 1] An electrophoresis display device, comprising a dispersion liquid for electrophoresis display in a sealed state between a pair of substrates opposed to each other, the electrophoresis display device being characterized in that the display-side substrate is formed of a transparent electrode and the non-display-side substrate is formed of an insulating material: and a series of operations, in which charges are applied to a local part or the entirety of the non-display-side substrate, then the accumulated charges are discharged or neutralized, and charges are applied again, are intermittently repeated so as to move the electrophoretic particles to obtain a desired display.

[Claim 2] An electrophoresis display device according to claim 1, characterized in that the discharge or neutralization takes a longer time period than the time period required for applying the accumulated charges.

[Claim 3] An electrophoresis display device according to claim 1 or 2, characterized in that the charges are applied in an ion-flow system.

[Claim 4] An electrophoresis display device according to any one of claims 1 through 3, characterized in that the applied charges are neutralized by ions having an opposite polarity in an ion-flow system.

[Detailed Description of the Invention]
[0001]
[Field of the Invention] The present invention relates to an electrophoresis display device. Specifically, the present invention relates to an electrophoresis display device which is freely put into a desired display ON state or display OFF state by repeating a series of drivings, in which charges are applied, next the charges accumulated in the electrophoresis display device are discharged or neutralized by charges having an opposite polarity, and then charges having an identical polarity to that of the initially applied charges are applied so as to discharge or neutralize the charges again.

[0002]
[Prior Art] In an electrophoresis display device of a DC driving system, oxidation and reduction of the dispersion liquid for display are induced by, for example, an electron inflow from the electrode to the dispersion liquid for display or an electron outflow. Such an electrophoresis display device involves instability, specific to DC driving display devices, due to factors such as, for example: a display change caused by the quality change in the dye which is one component of the dispersion liquid for display: or a quality change of the surfactant used for dispersing the

electrophoretic particles: dissolution of the electrode components into the dispersion liquid for display: or a combination of these obstacles.

[0003] As a solution to the instability, the display deterioration is prevented by sending and receiving charges between the dispersion liquid for display and the electrode using a so-called DC current blocking system. In accordance with the DC current blocking system, a surface of the electrode, which is to be in contact with the dispersion liquid for display, is coated with an insulating material so as to block the DC current.

[0004] Generally in order to matrix-drive an electrophoresis display device having no threshold, internal electrodes are arranged in, for example, a grid (document: P.C. Muraw, Proc. 5th Int 1 Display Research Con. P. 187, 1984) to electrically form a threshold by the internal electrodes. Alternatively, as the Applicant of the present application has proposed in Japanese Laid-Open Publication No. 4-166917 (Sotoyama), a driving external electrode is formed on a non-display-side substrate with an insulating material interposed therebetween using a through-hole method.

[0005]
[Problems to be Solved by the Invention] In the case of the former electrophoresis display device of the DC current blocking system, when the insulating layer is formed so as not to cause a dielectric breakdown of the insulating layer, the insulating layer becomes thicker and thus the capacitance is reduced. Accordingly, the insulating layer is charged immediately after the DC voltage is applied, and thus a voltage is not applied to the dispersion liquid for display. As a result, complete display is not realized.

[0006] In the case of the latter system, the structure is complicated, and the materials and display shape are constrained.

[0007]
[Means for Solving the Problems] The present invention provides an electrophoresis display device which is freely put into a desired display ON state or display OFF state by repeating a series of drivings, in which charges are initially applied, next the charges accumulated in the electrophoresis display device are discharged or neutralized by charges having an opposite polarity, and then charges having an identical polarity to that of the initially applied charges are applied so as to discharge or neutralize the charges again.

[0008] According to the present invention, in an electrophoresis display device comprising a dispersion liquid for electrophoresis display in a sealed state between a pair of substrates opposed to each other, the electrophoresis display device being characterized in that the display-side substrate is formed of a transparent electrode and the non-display-side substrate is formed of an insulating material: and a series of operations, in which charges are applied to a local part or the entirety of the non-display-side substrate, then the accumulated charges are discharged or neutralized, and charges are applied again, is intermittently repeated so as to move the electrophoretic particles to obtain a desired display.

[0009] In the above electrophoresis display device, the discharge or neutralization can take a longer time period than the time period required for applying the accumulated charges. The charges can be applied in an ion-flow system.

The applied charges can be neutralized by ions having an opposite polarity in an ion-flow system. Furthermore, the device can be structured so that the applied charges are discharged a plurality of times by the contact with the electrode which is grounded at a high resistance.

[0010]
[Examples] Hereinafter, the present invention will be described in more detail by way of an example shown in the Figures. Figures 1 through 3 are conceptual views of an electrophoresis display device structured according to the present invention. Reference numerals 1 and 2 respectively represent a transparent glass plate and a necessary transparent electrode pattern formed on an inner surface of the transparent glass plate. The transparent glass plate and the transparent electrode pattern can form one necessary substrate in the form of a so-called IT0 glass electrode.

[0011] The other substrate is formed of an insulating material 3 having no electrode. The substrate is opposed to the electrode pattern 2 and apart therefrom by a necessary distance. A dispersion liquid 4 for display, optimally prepared so that electrophoretic particles 6 are dispersed in an appropriate dispersion medium, is accommodated in a sealed state between the substrate and the electrode pattern 2. As described below, moving electrophoretic particles 7 are acted on in relation with the capacitance between ions 5 applied to an external surface of the insulating material 3 by an ion-flow system by an ion gun 8 and the insulating material 3. The ion gun 8 includes a discharge wire 9 and a control electrode 10.

[00121 The present invention having the above-described structure operates as described below by the ion-flow system

for neutralizing applied ions with ions having an opposite polarity.

[0013] A voltage application circuit can be represented by an equivalent circuit shown in Figure 4. In this figure, letter E represents a DC source, letter S represents a switch, letter C_1 represents a capacitance of the insulating material 3, letter C_2 represents a capacitance of the dispersion liquid 4, and letter R represents a resistance of the dispersion liquid 4. Since $C_1 > C_2$ in general, the voltage V applied to the dispersion liquid 4 can be simply represented by:

$$V = E \cdot \exp(-C_1 \cdot R)t \quad \ldots\ldots (1)$$

Herein, for example, the insulating material 3 is a PET film of 50 μm, 70 cm^2, and 3.7 nF, and the resistance of the dispersion liquid 4 is 500 kΩ.

[0014] First, as operation 1, negative ions are applied (10^{-4} A/cm^2, application time: 0.1 ms) to the insulating material 3 (PET film) by the ion gun 8 as shown in Figure 1. By such an application, the insulating material 3 has a charge of 10^{-8} Coulomb/cm* in a charged state and a voltage of 190 v. In such a case, the voltage is applied to the dispersion liquid 4 for only a short time period (time constant: 1.85 ms) based on expression (1), and a general response time of the electrophoretic particles is several ten to several hundred microseconds. Accordingly, the electrophoretic particles 7 move toward the electrode pattern 2 of the ITO glass but cannot be in an ON state completely.

[0015] Next, as operation 2, positive ions are applied by the ion gun 8 at a lower current density (10^{-5} A/cm^2, application time: 1.0 ms) than the negative ions as shown in Fig-

ure 2, thereby neutralizing the negative ions in operation 1. Such an operation moves the electrophoretic particles 7 back toward the insulating material 3, but the moving distance is shorter than that when the negative ions are applied.

[0016] Then, operations 1 and 2 are repeated until a desired display brightness is obtained as shown in Figure 3.

[0017] Figure 5 is a circuit diagram for applying positive ions. Reference numeral 11 represents an electrophoresis device having the above-described structure. Reference numeral 12 represents an electrode, which includes an upper electrode part 13 and a lower electrode part 14. The ion gun 8 is provided above the electrode 12. Reference numeral 16 represents a high withstand voltage MOS including transistors 17 and 18 connected in series. Control terminals of the transistors 17 and 18 are connected to a control terminal 24 of a computer. Reference numeral 19 represents a resistor connected to the discharge wire 9 of the ion gun 8. Reference numerals 20 through 23 represent DC power supplies of 400 v, 200 v, 1 kV, and 4 kV through 10 kV, respectively. A series connection point between the DC power supplies 21 and 22 and an output of the transistor 18 are connected to the ion gun 8. The upper electrode part 13 is connected to a series connection point between the transistors 17 and 18, whereas the lower electrode part 14 is connected to a series connection point between the DC power supplies 20 and 21.

[0018] The circuit operates in the following manner. Positive ions generated by corona discharge can be controlled to pass or to be blocked by the upper and lower electrode parts 13 and 14 of the electrode 12 having an ion passage hole 15. For example, when the MOS transistor 17 is ON and the other transistor 18 is OFF, the upper electrode part 13 has 1600 V

and the lower electrode part 14 has 1200 V. Thus, an electric field is generated in a direction forward with respect to the display device 11. Therefore, the positive ions can pass through the ion passage hole 15, so that the ions are applied to the display device 11. By contrast, when the transistor 17 is OFF and the transistor 18 is ON, the upper electrode part 13 has 1000 V and the lower electrode part 14 has 1200 V. Thus, the electric field is in an opposite direction to that of the display device 11. Therefore, the positive ions cannot pass through the ion passage hole 15, so that the application of the ions can be stopped.

[0019] When the ion gun 8 is switched over, and the connection between the MOS transistors 17 and 18 and the connection between the electrodes 13 and 14 are switched over, the display can be changed by application of the opposite polarity.

[0020] As can be appreciated from the above description of the operation, a necessary matrix display can be easily realized by performing the above operation while performing the scan-driving using ion gun devices provided in an array.

[0021]
[Effect of the Invention] According to the present invention, the electrophoresis display device, in which at least one of the substrates is formed of an insulating material, is structured so that, when an electric field is applied to the electrophoresis display device in order to move the electrophoretic particles by capacitance, the electric field is applied a plurality of times while the polarity of the electric field is changed. As a result, the electrophoresis display device can achieve a desirable display ON state or

display OFF state with certainty while the wiring is facilitated and the display can be remotely driven.

[0022] In the case where ion gun devices arranged in an array are used as means for applying an electric field, a matrix display can be easily performed by appropriately scan-driving the ion gun devices.

[0023] Such an electrophoresis display device, which can be structured easily regardless of the size of the display area and can perform display in an easy manner, is optimum among this type of electrophoresis display devices.

[Brief Description of the Drawings]
[Figure 1] A conceptual view for illustrating an operation of an electrophoresis display device according to the present invention.

[Figure 2] A similar view for illustrating a subsequent operation.

[Figure 3] A similar view for illustrating a still subsequent operation.

[Figure 4] An equivalent circuit diagram of a voltage application circuit in the electrophoresis display device according to the present invention.

[Figure 5] A circuit diagram, for applying positive ions, in the electrophoresis display device according to the present invention.

[Description of the Reference Numerals]
1 Transparent glass plate

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2' Electrode pattern
3 Insulating material
4 Dispersion liquid for display
5 Ions
6 Electrophoretic particles
7 Electrophoretic particles
8 Ion gun
9 Discharge wire
10 Control electrode
11 Display device
12 Electrode
13 Upper electrode part
14 Lower electrode part
15 Ion passage hole
16 High withstand voltage MOS
17 MOS transistor
18 MOS transistor
24 Control terminal

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[Abstract]
[Objective] To provide an electrophoresis display device which is freely put into a desired display ON state or display OFF state by repeating a series of driving, in which charges are initially applied, next the charges accumulated in the electrophoresis display device are discharged or neutralized by charges having an opposite polarity, and then charges having an identical polarity to that of the initially applied charges so as to discharge or neutralize the charges again.

[Structure] In an electrophoresis display device, in which a dispersion liquid 4 for electrophoresis display is interposed, in a sealed state, between a pair of substrates opposed to each other, at least one of which is formed of an insulating material 3 and has no electrode, an electric field is applied to the dispersion liquid 4 through a capacitance of the substrate formed of insulating material 3 so as to change a distribution state of electrophoretic particles 6 and 7 in the dispersion liquid, thus realizing a desired display operation, the electric field being applied a plurality of times while the polarity of the electric field is changed, the polarity being based on the operation of an ion gun 8 for moving the electrophoretic particles 7.